30 Spondylolysis

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Spondylolysis is a bone defect that affects the pars interarticularis of a vertebra (Fig. 30.1). The pars interarticularis is a small isthmus located between the facet joints of the vertebrae above and below. This usually occurs on a bilateral basis, affecting the L5 (85–95%) and on rarer occasions affecting the proximal lumbar vertebrae [1–3], the affectation of which is usually unilateral. An isthmic unilateral lesion is observed in 14–30% of cases [4–6]. It may be associated with injuries at other levels or with lysis on the contralateral side, which develops over time. Although it is rare, it may affect several levels simultaneously [7].

Spondylolisthesis is understood as the displacement of a vertebra on the one immediately below (Fig. 30.2). Said displacement will occur more frequently in the lumbosacral junction.

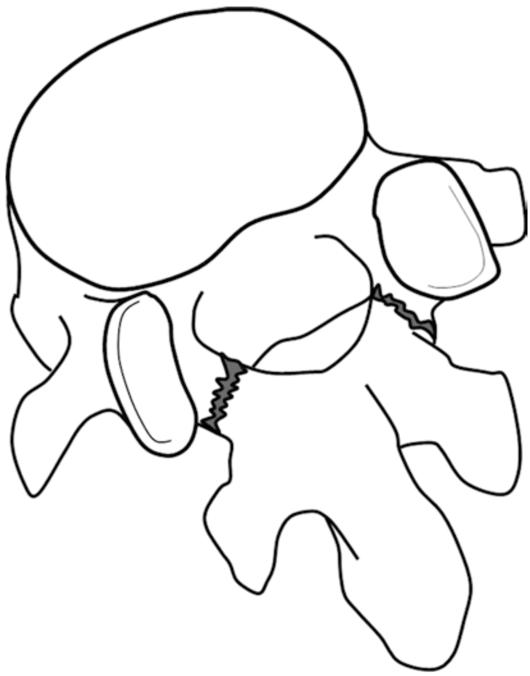

Fig. 30.1 Spondylolysis. Defect in the pars interarticularis

Spondylolisthesis in the adolescent population can be developmental, with dysplastic pars or other posterior elements, isthmic (related to pars fracture) or secondary to tumour or trauma of the posterior elements [8]. Its prevalence in the Caucasian population is around 5%, while the isthmic spondylolisthesis appears in 25–30% of the first [1, 9].

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Fig. 30.2 Spondylolisthesis. Anterior displacement of a spinal body

30.1 Epidemiology

Spondylolysis is considered to be a stress fracture [10, 11], appearing in approximately 3–13% [1, 4, 12, 13] of the Caucasian population, with an increase in this prevalence in certain ethnic [14], sports [15, 16] and family groups [17]. The defect in the pars interarticularis is an entity that appears during childhood and does not increase significantly in adulthood [9]. The isthmic lesion affects men more than women [9, 17], although it seems that the latter develop greater olisthesis [18].

In a study conducted by the Royal Spanish Tennis Federation, retrospective analyses were carried out on 66 young tennis players in whom spondylolysis with or without spondylolisthesis was diagnosed between 2002 and 2004 [19].

A total of 66 cases of spondylolysis were studied, 42 men and 24 women, with a mean age of 14.8 years (range 12–21): 53 (80%) cases were at L5, 8 cases (12%) were at L4, 2 cases (3%) were at L3, and 1 (1%) bilateral case was at L2. Two more two-level cases were found (bilateral L5 and unilateral L4 and L3 on the right side).

The injured tennis players with pathological entities were classified on the basis of their performance in supplementary tests: 27 (mean age of 15.1 years (range 12–21); 17 men and 10 women) had developing spondylolysis (negative radiography, positive PBS/SPECT), 20 (mean age of 14.8 years (range 12–18); 12 men and eight women) had active lysis (positive radiography, positive PBS/SPECT) and 19 (mean age of 16.6 years (range 14–20); 13 men and six women) had established spondylolysis (positive radiography, negative PBS/SPECT).

The results of this study show a higher incidence rate of spondylolysis of what is seen in most current literature. This may be due to spondylolysis being so much more common in adolescents because the spine is still undergoing growth and remodelling, and the pars interarticularis does not reach bone maturity until an approximate age of 25 years [20].

30.2 Etiopathogenesis

In relation to spondylolysis, there are certain general predisposing factors which are widely described in the literature such as genetics [21, 22], age and gender [12, 13, 23], race [9, 12] and the structure of the pars [24] and of the rachis, of which the triggering factor is mechanical overload, especially the one that occurs during hyperextension and lumbar rotation [20, 25].

In the world of tennis, the combined movement of extension with forced rotation during the forehand stroke may be a contributing factor in the onset of isthmic lesions in young tennis players. Although introduction of a stance facing the trajectory of the ball seems to have increased the speed of the stroke, it has also increased overloading of the posterior arch [19]. Also, specific actions that cause overloading of the posterior arch of the vertebra are hyperextension when serving and the combined movement of extension with forced rotation during the forehand [19].

In recent years there has been a change in the characteristics of playing tennis. The change of materials involving rackets, strings, courts or event balls leads to an increase in speed and power of the shots, which require greater approximation to the ball and a much faster exit after hitting the shot. This leads to more abrupt lumbar rotation (with an associated flexo-extension) and more powerful impact in forehand and backhand.

It has been discussed whether this increase in rotation load to the spine is due more to the mechanism of the serve (where a forced hyperextension—lumbar flexion—takes place with a greater or lesser rotational component depending on the type of serve used) or in the forehand or backhand. In our experience in the Spanish Federation, we believe that at present, the forehand or backhand shots are more aggressive than the serve for a possible injury in the form of spondylolysis.

These mechanisms and movements of the game along with a weakness of the abdominal muscles and excessive rigidity of the hamstring muscles cause this stress reaction affecting the lumbar spine with a higher percentage among the sporting community [26].

In fact, the prevalence of isthmic injuries among the sporting community increases in comparison to the Caucasian population that does not play sports by about 10–20% [19, 20, 25]. Isthmic injuries are seen in sports with a predominance of flexo-extension (gymnastics [23], butterfly-style swimming [27]) sometimes associated to rotations (tennis [19], high jumping [28] and/or sports with simultaneous loading such as weightlifting, diving or taekwondo) [20, 29].

One of the main complications of spondylolysis with an evolution over time is the appearance of spondylolisthesis. These are classified based on the Wiltse, Newman and MacNab's classification (1976) [30] which distributes spondylolisthesis into five different types. In sports we generally come across isthmic spondylolisthesis (type II) and, sometimes, dysplastic spondylolisthesis (type I).

30.3 Clinical Findings

Clinically, there are three types of pain associated with the isthmic and/or olisthesic injuries: lumbar pain caused by isthmic injury, lumbar pain related to an alteration to small joints and radicular pain associated to a lesion to the pars [19, 20].

Pain resulting from isthmic lesion (with or without olisthesis). Isthmic injuries often progress without symptoms [31]. It is calculated that up to 80% of cases are asymptomatic [32]. In this case, individuals who submit the rachis to repetitive extension or rotation are those who most often develop pain. This fact would be related to the biomechanical mechanisms producing the lesion mentioned above and evidently, among the sports community, in which a precise diagnosis will be essential [33].

The beginning of the pain is normally progressive and mechanical, although there are also references to sudden appearance or acute worsening of the picture after a fortuitous accident [8, 19].

It presents itself as a lower lumbar pain, with irradiation to buttocks and sometimes to the thighs, often disabling [8, 9, 16, 19, 20]. For Standaert and Herring [16], the only pathognomonic manoeuvre is possibly the one that involves a combined hyperextension of the hip and lumbar spine, keeping the individual on the other leg. This test is useful in unilateral spondylolysis, given that the pain appears when the patient puts weight on the healthy side. The pain is often associated to a reflected contracture of the hamstrings, a lumbar position in hyperlordosis [34] and a certain degree of scoliotic posture [35].

The reflected contracture of the hamstring has been associated to an irradiation of the nerve root or to an attempt to control the stability of the lumbosacral junction.

Lumbar pain related to alteration of the small posterior joints (facet syndrome). It is characteristic, but not inherent to spondylolysis already present or spondylolisthesis. It is related to a certain degree of lumbar instability or with a defective function of the olisthesic segment. Some authors consider the instability as responsible for the majority of lumbar pains in segments with isthmic lesion [36]. These would be false sciatica or pseudo-sciatica.

Lumbar pain of root type. The patient more rarely suffers radicular or root pain in one or both lower limbs associated to lower lumbar pain. These symptoms are found more frequently in frank spondylolisthesis. Young people, unlike adults, rarely show objective signs of nerve compression, such as motor weakness, alterations in any deep tendon reflexes or sensory deficits [37].

30.4 Diagnosis

The correct evolution of spondylolysis in teenage sports people depends to a great extent on early diagnosis. Therefore, when a sports person suffers acute lumbar pain or lasting pain, with greater or lesser radiculopathy, while also suffering pain with lateral moves and lumbar rotations and during one-legged lumbar hyperextension test and with reduced flexibility of the isquiosural muscles, the presence of spondylolysis must be ruled out.

For this, regardless of the clinic, there are four complementary tests each of which with different properties and characteristics. At all times, the combination of the clinical history with one or more of these tests will give a very accurate idea of the moment of the natural history of the lesion.

(1) *Conventional radiology*. This is a very specific yet hardly sensitive test [38]. These limitations are partly due to the spatial orientation of the defect. It is advisable to perform the A/P view with a 30° of axial deviation [19, 20, 38].

The most objective image of the lesion is provided via an oblique view (Fig. 30.3). This is provided through a 45° obliquity of the ray. The lesion is typically described as a puppy with a collar or "decapitated", according to the state of mind of the observer. It is recommended that the X-rays are taken while standing, given that an apparent spondylolysis in supine position can be revealed as a spondylolisthesis when standing. Between 16% and 20% of X-rayed spondylolysis are only seen through a conventional oblique view [39].

A side view (Fig. 30.4) is capable of objectifying a large number of spondylolyses and is ideal in the diagnosis of olisthesis. Equally, functional views are important given that in spondylolisthesis these will objectify any possible instabilities [40, 41], while its use is more limited in the case of spondylolysis.

(2) *Bone scan and SPECT*. Becoming aware of the physiopathology of injuries caused by overloads is due to a great extent to bone scans with technetium^{99m}-MDP combined with a tomographic technique (SPECT). A bone scan (Fig. 30.5a) is highly sensitive but not very specific [42]. The bone scintigraphic study provides an idea of the metabolic activity of the injury and whether it is a recent or old injury. Bone scan with or without SPECT technique is the only test that assesses, with great sensitivity, whether the bone injury is metabolically active [20, 38, 42, 43].

The SPECT technique (Fig. 30.5b) improves both the sensitivity and specificity of the bone scan and simple X-ray study [16, 19, 20, 30,

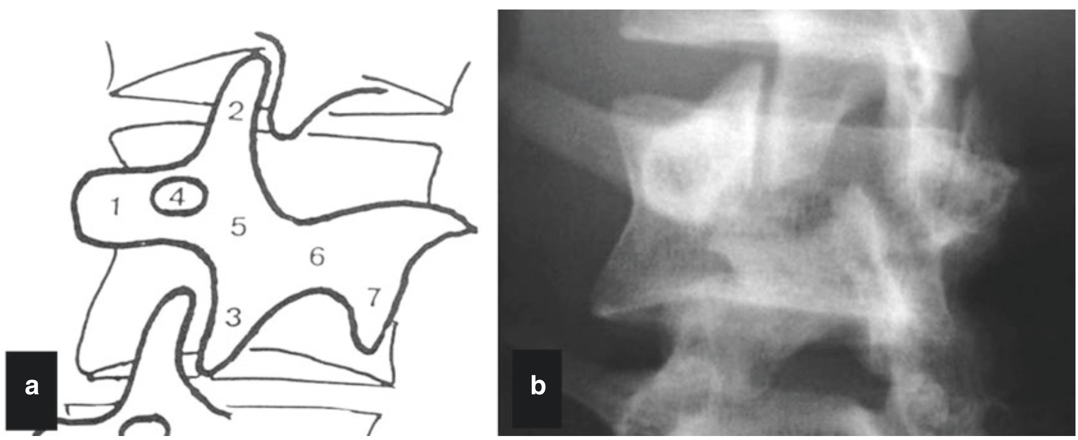


Fig. 30.3 (**a**) Oblique view of spondylolysis. 1, transverse process; 2, upper articular facet; 3, lower articular facet; 4, pedicle; 5, isthmus; 6, lamina; 7, spinous process. (**b**) 45º oblique projection of an isthmus injury

Fig. 30.4 Lumbar spine lateral view. Spondylolysis image (*arrow*) with a mild displacement of the L5 vertebra over the sacrum

42–45]. It provides information of when the injury occurred and, with this, the treatment to be followed [16, 19, 20]. The sensitivity of the bone scan for detecting spine injuries, especially in the posterior elements of the vertebrae, is significantly increased when using in combination with SPECT [44, 45]. In the lumbosacral spine, the bone SPECT increases the sensitivity by 20–50% in comparison to the planar study.

3. *Computed tomography (CT)*. The CT (Fig. 30.6) is considered to be of greater sensitivity than conventional radiology and more specific than the SPECT [44, 45]. Regardless of the cut performed, the CT will provide information on the status of the defect (acute fracture, nonconsolidated defect with geodes and sclerosis, consolidation or repair process of the pars) [46].

The *reverse gantry* view, perpendicular to the conventional, provides a greater view of the injury. It provides us with valuable information on the characteristics of the edges of the isthmic defect.

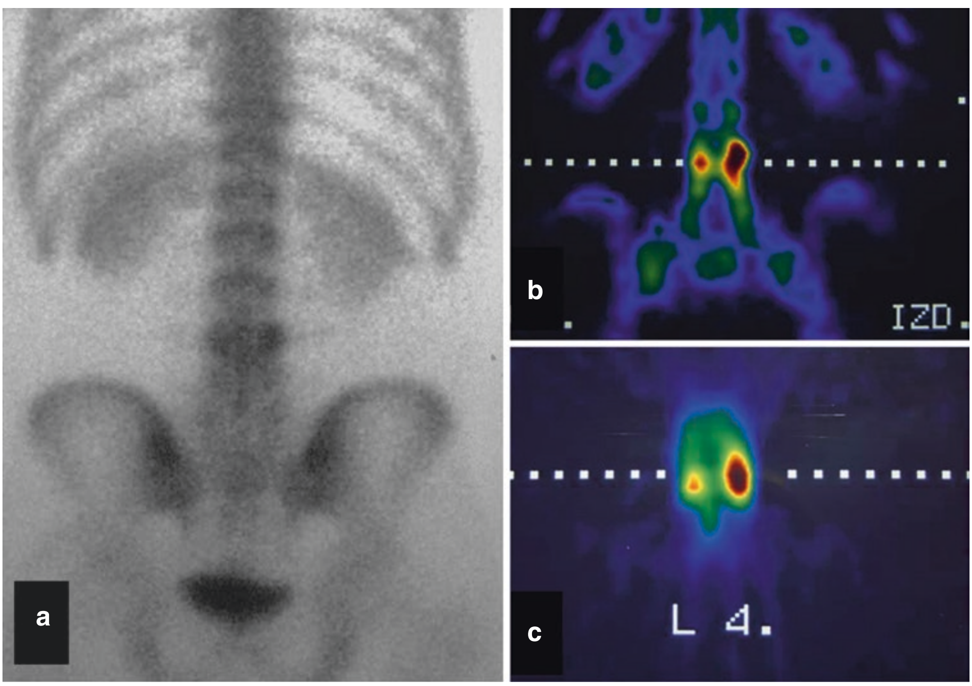


Fig. 30.5 (**a**) Planar bone scintigraphy image with increased uptake of the left L4 spinal bone comparing with right. SPECT bone examination coronal (**b**) and axial (**c**) image with the same increased uptake

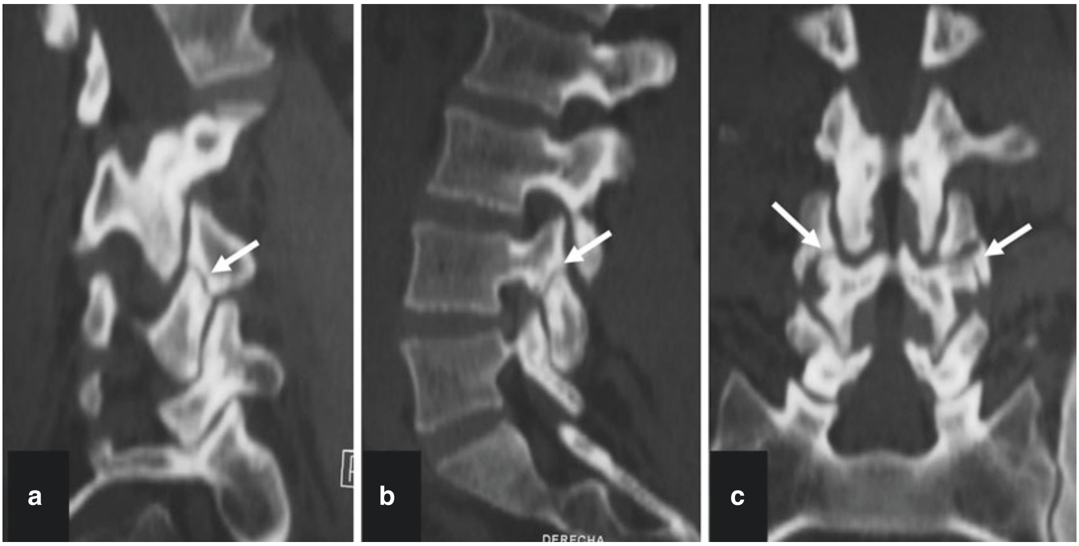


Fig. 30.6 Obliquely (**a**), sagittally (**b**) and coronally (**c**) reconstructed CT of the lumbar spine shows a defect of the pars interarticularis on the L4 (arrows). In coronal view is visible bilateral injury

4. *Magnetic resonance*. **It** allows to assess the injuries which are also associated to objectifying the isthmic injury [46]. The normal *pars* is viewed better in the T1 sequence than in T2 sequence. This technique objectifies that only three quarters of the *pars* are strictly normal [23, 47]. The MRI is also useful for assessing the fibrocartilaginous mass which develops at *pars* defect level (Gill's module).

The MRI is capable of detecting spondylolysis early on (Fig. 30.7). MRI allows for early objectivation of signal changes at *pars* level which are catalogued as "stress responsive" of the same and can be classified into different degrees of activity [48].

As discussed above, early diagnosis of the pathology is essential. Thus, in light of clinical suspicion of a spondylolysis, it is recommended to first request a bone scan with SPECT to obtain or rule out the diagnosis and, then, carry out follow-up MRI studies (except in specific cases in which it is believed that control should be carried out by means of bone scan with SPECT to assess the metabolic activity of the lesion). The use of CT is reserved for cases in which the exact pars defect is to be determined.

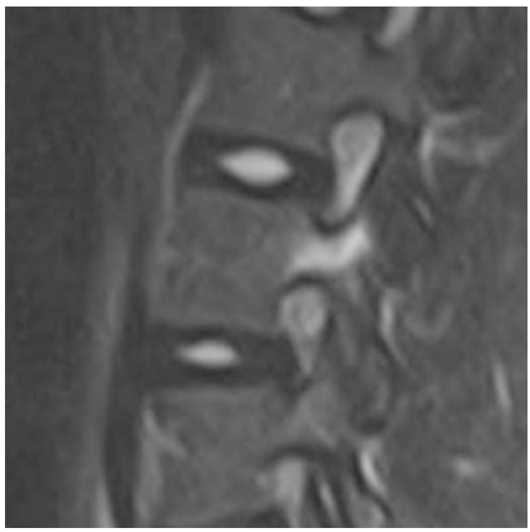


Fig. 30.7 Sagittal MRI image shows well-limited stress reaction in the pars interarticularis

30.5 Prognostic Factors

One of the main concerns is the progression to spondylolisthesis. In general, in sports, the risk of a spondylolysis, either with or without a low-grade spondylolisthesis, progressing to greater slipping is low [16, 19, 20]. The progression of the slippage can be seen in teenagers during growth spurts, and it seems that the initial slippage is greater in females [49].

Different factors have been proposed as prognostic factors: dysplastic alterations associated to the isthmic injury, degree of associated disc degeneration and instability. These last two concepts are closely related to each other given that disc degeneration involves instability, and this instability can be assessed by means of an MRI study of dynamic functional radiology.

Associated dysplastic alterations. The olisthesis that is typically from practising sports is the isthmic variation. However, the physician must identify whether the olisthesis is of a dysplastic origin, given that by definition the olisthesis may be greater. Having spina bifida occulta (SBO) is a prognostic factor for suffering a *pars* lesion or greater olisthesis [12, 16, 20, 50]. Equally, the dysplastic lumbosacral morphology is a predisposing factor to suffering spondylolysis with or without olisthesis. These are two alterations to be considered: the trapezoidal aspect of the fifth lumbar vertebra and the console shape of the upper surface of the sacrum. Observing these two alterations provide a simple way of assessing the possible progression or lack of (Fig. 30.8).

Associated disc degeneration. It has been proven that there is correlation between disc degeneration and spondylolysis and spondylolisthesis. Disc degeneration could facilitate olisthesis [37].

The disc degeneration process that occurs in parallel to the listhesic phenomenon goes through three stages [51]. First is *dysfunction*, in which there are minimum pathological changes in the disc, without causing alteration in its functionality. Second is *instability*, in which the height of the disc decreases and all the fibrous rings distend around the circumference transversally drawn by the disc. Third is *re-stabilisation*, the stage presided by the fibrous and osteophytic stabilisation of the segment.

Currently, by performing MRI the control and/or diagnosis of spondylolysis in young athletes leads to more and more examples of these small disc degenerations at earlier ages.

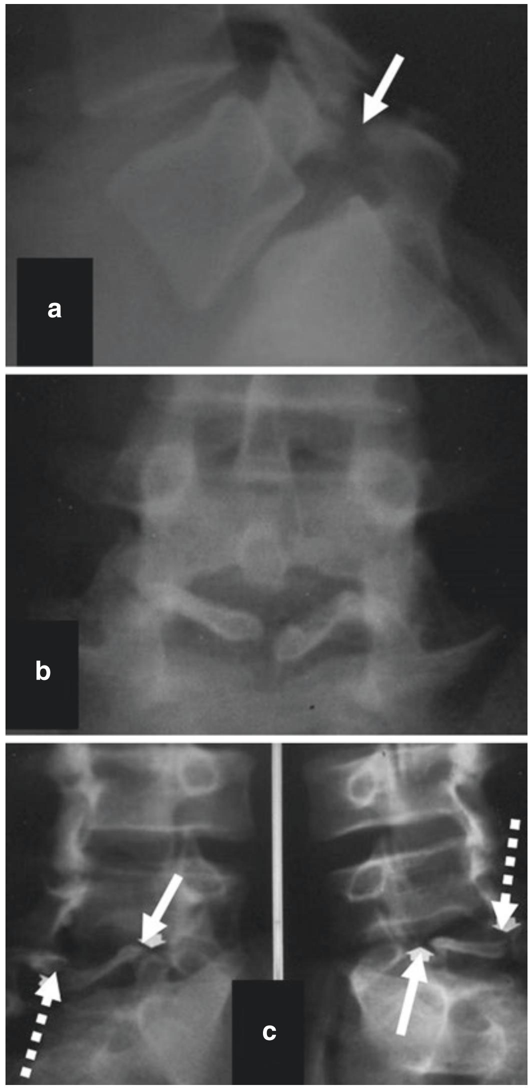


Fig. 30.8 Radiographic study of the lumbar spine shows spondylolysis at L5 (arrows) in lumbosacral dysplasia. (**a**) Sagittal view shows trapezoidal spinal bone with sacral promontory in S italic. (**b**) Frontal view shows spina bifida occulta at L5 related to injury. (**c**) Bilateral oblique view shows "floating sheet" limited by spondylolysis and spina bifida occulta (discontinuous arrows)

Instability. The instability from a clinical point of view is the loss of the capacity of the rachis, due to physiological overload, to maintain its position between vertebrae, in such a way that

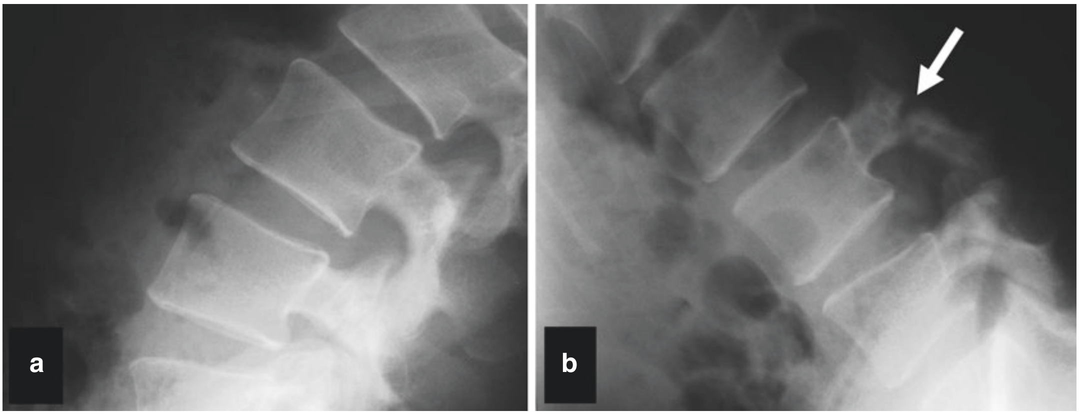


Fig. 30.9 Lateral view—extension (**a**) and flexion (**b**). A mild instability is observed that allows objectifying the isthmic defect during the flexion

there will be a lesion due to the instability itself and the subsequent irritation of the spinal canal or of the nerve roots. This disc functionalism is widely variable depending on age, gender, flexibility (obesity-thinness) or even in the same individual in different radiological examinations [38, 52]. The functional radiological examination must be performed under solely clinical criteria, observing the uniform closure of the discs to obtain a harmonious and regular lumbar curve [38, 52].

When performing radiological studies of the lumbar spine in maximum flexion and extension or with different types of loads, this often confirms, especially in the early stage of slippage, the presence of exaggerated mobility of the olisthesic vertebrae [52].

A dynamic study can be very useful for detecting some cases of lysis, of unnoticeable displacements in conventional standing examinations, and especially in the case of isthmic lesions in athletes (Fig. 30.9) [38].

As a criterion of instability, one assesses an abnormal movement exceeding a 12° dynamic angulation or an 8% intervertebral movement [53].

Another prognostic factor that should be considered, especially in tennis players, is that the pathology affects L5 and/or appears between the ages of 12 and 16 years as this is when athletes are undergoing their development process.

30.6 Treatment

Except for advanced cases and those with associated complications, the treatment of spondylolysis in tennis players is conservative. The reconstruction of the *pars* can be done using different types of support braces [16, 19, 20]. These may be rigid or soft and can exert on the rachis an anti-lordotic action or simply limiting lumbar extension [19].

The major discussions are in relation to the length of time this support brace should be worn for. In this sense, there are works that recommend 2 or 3 months' immobilisation or less and other recommend up to 6 months. We must also take into consideration that in many cases, excellent clinical results are obtained without the reconstruction of the pars, which is visible in X-rays, while isotopic or MRI tests show no activity [19, 20, 26, 54].

It must be noted that an isthmic lesion can be classified as *lysis in formation* (with osteogenesis activity objectified through SPECT and negative radiology), *active lysis* (with increased uptake SPECT and lesion visible through conventional radiology) or *silent or terminal lysis* (positive radiology with negative isotope study) [55]. Adapting this classification to the various studies consulted, the isthmic reconstruction of these has been seen in *forming* lesions and has been virtually non-existent in *silent or terminal lysis* and sometimes possible in *active lysis*. On the other hand, it seems that reconstructions are more likely to occur in cases involving unilateral lesion.

It is clear that when faced with an isthmic lesion that produces symptoms, the steps to follow will include athletic rest and avoiding associated activities that increase lumbar pain.

This treatment by means of wearing a support brace and athletic rest must be associated to carrying out lumbar recovery exercises that will be incorporated gradually as of the third or fourth week of wearing the support brace.

When conservative treatment fails, the recommendation would be to undergo surgical treatment, which becomes necessary in 9–15% of the cases of spondylolysis and/or low-grade spondylolisthesis. These are cases in which the slippage is progressive, the pain is untreatable or the lumbar pain is associated to neurological deficit or spinal instability [16, 20, 56].

30.7 Pathological Situations to be Considered

To determine the conduct to be implemented, we must take into account the biological age of the athlete, his/her growth potential and the symptoms suffered. All this is considered along with the results of the different complementary tests, to find out which stage the isthmic injury is at. In teenage tennis players, there are two possible situations based on their age and the existing injury:

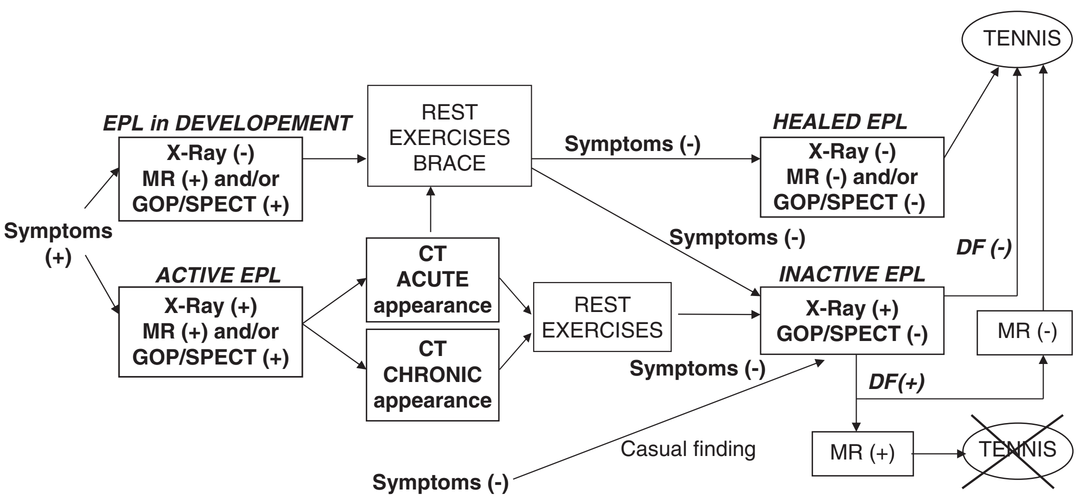
– Child or teenager with spondylolysis
– Child or teenager with spondylolisthesis

30.8 Child or Teenager with Spondylolysis (Algorithm 1)

In a child or a teenager, faced with the suspicion of isthmic injury, we would initially carry out a radiographic study with postero-anterior, lateral and oblique projections at 45° associated to a SPECT bone scan. Based on these results, if necessary, the study may be complemented by a scan. There are three pathological situations which we may have to face.

30.9 Spondylolysis in Formation

It is very important that the pathology is diagnosed during this stage, as the prognosis improves considerably and the necessary treatment tends to



Algorithm 1 Algorithm to follow in an EPL in a child or adolescent

be less. Spondylolysis is suspected in an athlete that is seen due to suggestive lumbar pain and with reaction to stress observed in MRI or uptake bone scan with SPECT at isthmic level, even though the X-ray does not show lytic image. The corresponding formula will be:

clinic (+) + X-ray (−) + MRI (+) and/or bone scan/SPECT (+)

Faced with this situation, athletic rest is recommended. The patient may use a support brace until reaching negative tendency of the clinic and evident reduction in the sign shown in the MRI or the bone scan SPECT. The type of support brace, flexible or not, rigid or soft, must be optional and will ultimately depend on the physician responsible for the athlete. The objectives of the immobilisation are to repair the *pars* deffect and to reduce the pain. The time which the brace should be worn and the type of brace is highly variable. Within the Spanish Tennis Federation, as these are young individuals practising sports, often at a very high level, we consider that the brace should be worn for a minimum of 6 weeks. Thanks to which we will at least manage to eliminate the symptoms and in some cases the stabilisation and fusion of the pars.

It must be noted that if SPECT technique has been used; the negative tendency is hard to assess, as the great sensitivity of this method must be taken into consideration, given that it can capture minimum osteoblastic activities. Therefore, in many cases, we must consider the sharp decline in the uptake, associated to a total clinical improvement. The formula for this situation would be:

clinic (−) + X-ray (−) + MRI (−) and/or bone scan/SPECT (−)

In principle, when seeing a negative tendency, the athlete will be allowed to return to sports activities in a very progressive manner and not without previously implementing an in-depth stabilisation guideline at vertebral and lumbopelvic regions. On the occasions when the clinic is reactivated with pain and MRI (+) and/or bone scan/SPECT (+), the protocol will be applied again.

30.10 Active Spondylolysis

This situation is the one generally diagnoses either due to late consultation of the athlete or due to a lack of early diagnosis. This occurs when the studied clinic coincides with the existence of a radiologically verified lysis and a positive MRI and/or bone scan with SPECT. The corresponding formula will be:

clinic (+) + X-ray (+) + MRI (+) and/or bone scan/SPECT (+)

In light of this clinical picture and image, athletic rest is essential until seeing a clear reduction in the stress reaction shown by the MRI and/or reduction in uptake of the bone scan/SPECT. The use of a support brace will depend on whether an MRI or CT are performed, as these offer an image of the bone structure of the pars.

If the CT scan or MRI shows an image of continuity solution with sclerosis on the edges, periosteal reaction in the recent defect, geodes and irregular periosteal reaction, the use of a flexible support brace will be discouraged. The simple observation of the separation between the edges of the defect may lead us to think of greater difficulty for consolidation.

In the event of the edges of the fracture being clean and of recent appearance, using an immobilising support brace can be of great help and also optional.

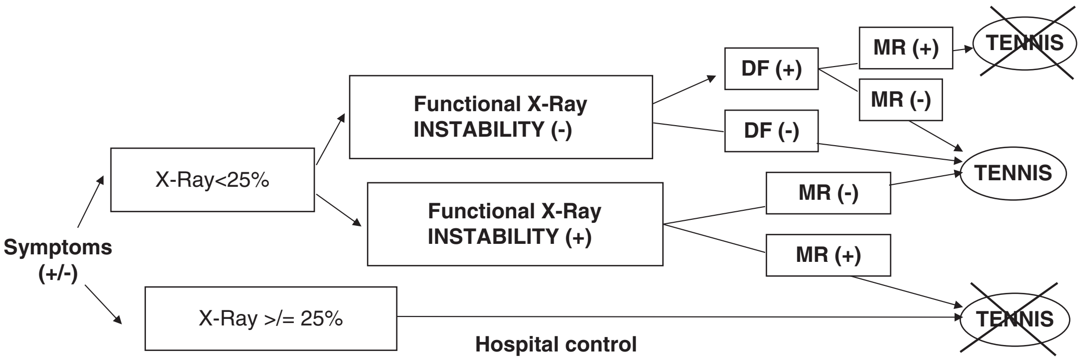
The formula to consider for assessing the inactivation will be:

clinic (−) + X-ray (+/−) + MRI (−) and/or bone scan/SPECT (−)

In this case it can be seen that the isthmic lesion will be repaired or not in X-ray imaging, mainly depending on the condition of the pars when subjected to CT scan and the conduct to be followed. This would allow to reach the healing that could be summed up in this formula:

[clinic (−), X-ray (−), MRI (−) and/or bone scan/SPECT (−)]

or to the last diagnostic possibility, inactive spondylolysis.



Algorithm 2 Algorithm in EPLT in a child or adolescent

30.11 Inactive Spondylolysis

This situation can be reached as of a case of active lysis or as a result of a casual finding in the course of a routine examination of the spine. The formula will be:

clinic (−) + X-ray (+) + MRI (−) and/or bone scan/SPECT (−)

When faced with this clinical picture, it is necessary to qualify according to the characteristics of the different cases. If the tennis player has a single dysplastic factor, or none, the athlete will be allowed to return to sports, regardless of the type and intensity of said sports.

On the other hand, if the tennis player is recreational and has more than one dysplastic factor (DF) associated to a marked disc alteration objectified by MRI, the athlete will be advised as a preventive measure to abandon tennis and turn physical activities that are less harmful to the lumbar spine.

In a tennis player with high-level growth, the latter will be allowed to continue playing the sport but reducing its intensity to avoid collateral exercises to tennis that could harm the lumbar spine.

30.12 Child or Teenager with Spondylolisthesis (Algorithm 2)

The conduct to be followed in the case of a child or teenager with spondylolisthesis is not only subject to the severity of the clinical picture. Whether there is lumbar pain or not and whether it irradiates or not, the conduct to be followed must be based on the existence of vertebral instability and the degree of disc degeneration. As a criterion of instability, we will assess an abnormal movement exceeding a 12° dynamic angulation or an 8% intervertebral movement.

30.13 Grade I Spondylolisthesis

In cases of spondylolisthesis with less than 25% displacement (grade I), we must assess the degree of instability this entails, as well as the associated disc degeneration. Therefore, a functional X-ray study and MRI must be carried out. As a criterion of instability, we will assess an abnormal movement exceeding a 12° dynamic angulation or an 8% intervertebral movement. In the event of not objectifying instability, the formula will be:

X-ray < 25%, instability (−)

In these cases, all sports may be practices, except when there is more than one dysplastic factor, situation in which an MRI must be carried out. If this shows signs of disc degeneration, the athlete will be advised to not play tennis.

If instability is objectified, an MRI must be carried out to assess the disc degeneration. When faced with a spine with grade I spondylolisthesis which is stable, without disc degeneration, the formula will be:

X-ray < or = 25% instability (+) MRI (−)

In this case the athlete will be allowed to play tennis at any level, regardless of the dysplastic factors.

When faced with lumbosacral instability with disc degeneration, the athlete will be advised to abandon playing tennis of any intensity.

X-ray < or = 25% instability (+) MRI (+)

30.14 Grade II or above Spondylolisthesis

When a teenage tennis player suffers from grade II spondylolisthesis, which corresponds to a percentage of 25% or above, this will force the athlete from abandoning all tennis regardless of its intensity. Equally, it is highly recommended that the evolution of the olisthesis is monitored at a hospital.

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